5-1962

The Mineral Resources of the Sevier River Drainage, Central Utah

David T. Sanders

Utah State University

THE MINERAL RESOURCES OF THE SEVIER RIVER DRAINAGE, CENTRAL UTAH

by

David T. Sanders

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Geology

UTAH STATE UNIVERSITY
Logan, Utah

1962

ACKNOWLEDGMENT

The author wishes to express appreciation to the Utah State University Research Council for financial assistance received and to the many owners, operators, and other interested citizens who have assisted in the accumulation of information here presented. To Dr. Donald R. Olsen, Dr. J. Stewart Williams, and Dr. Clyde T. Hardy acknowledgment is made for their critical review of the manuscript and other valuable assistance.

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Purpose and Scope

A survey of the mineral resources, the economic rock products, and the ground-water reserves of that part of central Utah drained by the Sevier River system was undertaken by the author in the fall of 1960 as a continuation of a research project directed toward the stimulation of economic growth in the state of Utah. The project was initiated in 1959 by Dr. Donald R. Olsen and Dr. J. Stewart Williams, who conducted a similar survey of a five county area in southwestern Utah (Olsen and Williams, 1960).

Through a review of existing literature, preliminary field examination of most of the important areas, and communications with owners, operators, and consulting geologists, an attempt has been made to include in this survey all of the important economic mineral and rock deposits. A review of the ground-water supplies of the region and a discussion of related problems are also included.

Each of the minerals and rock products is described alphabetically in a brief statement. This statement includes information concerning location, present status, present ownership, and geologic controls of accumulation. Where possible an estimate of the economic potential of each commodity is made. These estimates are based on accessibility, tonnage, grade, market value, etc. Each occurrence is also located on a map of the area (Plate 1).

Location and Extent

The Sevier River drains a large part of central and southwestern Utah. It heads in the Markagunt and Paunsaugunt plateaus in southwestern Utah and flows northward to the northern end of the Canyon Range, southwest of Nephi. Here its course turns westward and then southwestward across the Sevier Desert to Sevier Lake.

The extreme southern portion of this drainage lies within the five-county area included in the report of Olsen and Williams (1960). A paper by Nackowski and Levy (1959) on the mineral resources of the Delta-Milford area also includes part of the Sevier River drainage. Occurrences described in these two earlier reports were not extensively investigated in the current study but in some instances are referred to in order to present a more complete picture of the resources of the Sevier drainage.

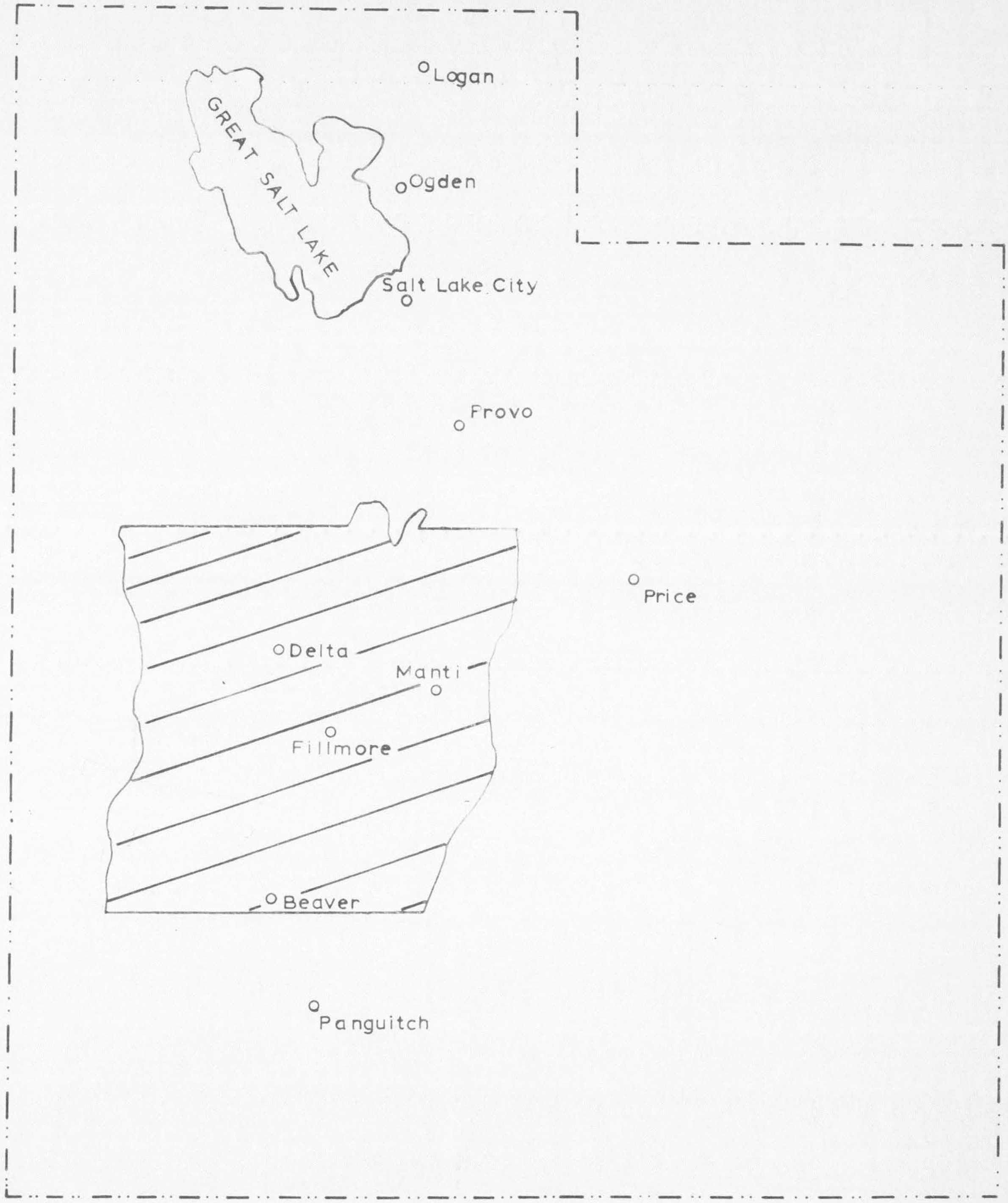

Figure 1. Index map

METALLIC MINERALS

General Statement

Although there are several metallic mineral mining districts within the area which have produced in the past and which still have producing potential, the metallic mineral production, with the exception of uranium production in the Marysvale region, is relatively low. This is primarily due to current market prices and high mining costs.

No metals are currently being mined in the districts in the higher elevations of the Tushar Mountains near the Piute County-Sevier County line, nor in the Main Tintic and West Tintic districts in Juab County. In the Ohio district, which includes the area immediately adjacent to the city of Marysvale, considerable uranium is being mined and shipped by the Vanadium Corporation of America. There is also some intermittent production of gold, silver, and the base metals from two or three individual properties on the east slope of the Tushar Mountains south of Marysvale.

In the Detroit district of the Drum Mountains, along the Juab County-Millard County line, manganese is mined and shipped for use as flux in Utah County steel mills. The manganese deposits of this district are the only ones active within the Sevier drainage, however.

The recent discovery of beryllium deposits in western Juab and Millard Counties has stimulated prospecting and development work. With the current demand for this strategic metal, there appears to be a good possibility for the development of a beryllium industry in this area.

Metallic Mineral Occurrences

Antimony

In the West Tintic mining district, which is located at the southernmost end of the Sheeprock Mountains in northern Juab County, stibnite is reported to occur with a number of other metallic minerals in pyrometasomatic veins in Paleozoic sediments about 600 feet from a monzonite intrusion (Stringham, 1942, p. 281). The stibnite occurs as a minor constituent in these veins and in the past was produced as a by-product from the Iron King and Tintic Western mines.

The West Tintic district became active in the 1870's but only limited production followed (Stringham, 1942, p. 268) and at the present time is completely inactive. A more complete description of the nature of ore deposition and the geology of the district is presented below where its more important mineral commodities are considered.

The only other notable occurrence of antimony in the Sevier River drainage is in the Coyote Canyon area of northern Garfield County. Here stibnite ore occurs as pods in conglomerate and sandstone beds of the Flagstaff formation of Tertiary age (Olsen and Williams, 1960, p. 1).

Beryllium

Within the last year west central Utah has been extensively explored for beryllium deposits and a number of significant discoveries have been made. The most important of these that lie within the Sevier drainage are located at Spors Mountain in the Thomas Range in Juab County. Here several of the beryllium minerals have been found both as vug filling crystals and as disseminated ore in rhyolite flows.

Very little information is currently available on the grade, tonnage, or occurrences of these deposits. There is every indication, however, that this area may become an important producer of this metal.

Bismuth

Bismuth minerals were found in several mines of the Main Tintic district, particularly in the Mammoth, Boss Tweed, and Emerald mines. In the Emerald mine small crystals of native bismuth were found in limestone independent of any other ore mineral. Native bismuth and bismutite assaying as high as 40 percent bismuth were mined in the Boss Tweed, while in the Mammoth mine the bismuth ore was mainly bismuth arsenate with some barite and occurred in percentages from 16.2 to 18.1 in gold-silver veins (Lindgren and Loughlin, 1919, p. 149). No bismuth is produced in this district at the present time because low metal prices and high mining costs have forced these mines, and all other metallic properties in the Main Tintic district, to close down.

Copper, gold, lead, silver, and zinc

Detroit district. The Detroit district is located in the Drum Mountains about midway along the Juab County-Millard County line. Its most important mineral commodity is manganese; however, small amounts of precious and base metals have been produced.

The mountain range consists of Paleozoic quartzite, limestone, and dolomite. These sedimentary rocks have been cut by small bodies of quartz monzonite porphyry occurring as dikes, sills, and stock-like bodies. The northern part of the range is capped by volcanic rocks. The ore deposits are bedding replacement deposits in the limestone and dolomite which overlie the quartzite (Nackowski and Levy, 1959, p. 56).

Leamington districts. The Leamington district is located southwest of Nephi about 30 miles. The district was organized in 1886, but production from the area was small. The only shipments from the district consisted of small amounts of silver-lead ore, although traces of gold, copper, and zinc were found in the district (Utah Mining Association, 1959, p. 58).

Main Tintic district. Nearly 12,000,000 tons of ore have been produced from the Main Tintic district since it was first opened in 1869. Silver, lead, and gold were the principal metals mined but significant amounts of copper and zinc were also produced.

The district is located on the western side of the East Tintic Mountains from the vicinity of Eureka southwest. It is the most important metal mining district in the Sevier drainage in total production and one of the most important in the state.

The East Tintic Mountains consist primarily of strongly folded and faulted sedimentary rocks which range in age from Pre-Cambrian to Permian and have a total thickness of over 32,000 feet. In the southern two-thirds of this range, the sedimentary rocks are covered by quartz latite and latite flows and pyroclastic rocks of middle Eocene age. Sedimentary and extrusive igneous rocks in the west-central part of the range are cut by quartz monzonite and monzonite stocks, plugs, and dikes. Associated with these intrusive rocks are the extensive silver, lead, copper, zinc, and gold ore bodies (Morris, 1957, p. 2). Nearly all of the rock types contain ore-bearing veins, but the principal mineralization is found in Paleozoic limestone and dolomite (Lindgren and Loughlin, 1919, p. 150).

Marysvale region. There are three precious- and base-metal mining districts in the Marysvale region, the Ohio, Kimberly, and Mount Baldy districts. The Ohio, or Marysvale, district was organized in 1868 with its principal mines in Bullion Canyon just west of the city. Here the Pre-Tertiary sedimentary rocks and the Tertiary volcanic rocks of the Tushar Mountains are folded into a broad north-trending anticlinal fold which has been greatly modified by faulting. Most of the faults are parallel to the axis of the fold and have provided the channels for the mineralizing solutions. East-west faulting is of minor importance except in upper Bullion Canyon where the intersection of north-trending and east-trending faults has localized the ore bodies (Evans, 1953, p. 103).

Although some high-grade ore was mined for several years and two mills were built in this district, the all-time production probably did not exceed a half-million dollars in value (Utah Mining Association, 1959, p. 63). There is still a little activity in the district. The DeLuke Mining Company of Marysvale maintains a small-scale operation at the Copper Belt mine, which is located just north of Bullion Canyon in California Gulch, and Lynn Burr and Ronald Jones, both of Marysvale, just recently began the development of a quartz-gold vein on the face of the Tushar Mountains near the mouth of Bullion Canyon that shows promise. All other properties in the district are idle.

The Kimberly district is situated high in the Tushar Mountains in the vicinity of the Piute County-Sevier County line. The district was organized in 1889 and became a substantial producer of gold and silver.

The metals produced were valued in the millions of dollars (Utah Mining Association, 1959, p. 63). Mr. Elmo Herring, of Austin, Utah, has plans to reopen one of these mines in Upper Kimberly but, for the most part, the district has been abandoned because of the high mining costs involved in exploiting the deeper lower-grade ores.

The ore in the Annie Laurie mine, the largest producing property in the district, occurs in well-defined veins cutting and restricted to dacite. These veins are believed to have formed by deposition from hot springs in fissures shortly after the close of a phase of volcanic activity (Lindgren, 1906, p. 89-90). Rhyolite and great masses of rhyolite tuff are also found in the area but they contain no known economic mineral occurrences.

The third mining district of the Marysvale region is the Mount Baldy district. This district is immediately south of the Ohio district, along the eastern face of Deer Trail Mountain. It was organized in 1878 (Utah Mining Association, 1959, p. 63) and has been active nearly continuously to the present time. Currently the Arundel Mining Company is engaged in mining operations in the district and makes periodic shipments of lead-zinc ore.

The steep face of Deer Trail Mountain on which most of the mines of the Mount Baldy district are located is an escarpment of the Tushar fault and is one of the only places in the Marysvale region where sedimentary rocks are exposed beneath the Tertiary volcanic rocks. The ore bodies occur in limestone replacements at several horizons in these rocks.

Salina district. There are several minor occurrences of lead and zinc in the vicinity of Salina. The ore occurs primarily as galena and sphalerite in veins of calcite along both normal and thrust faults. Many of the occurrences have been worked to some extent but little ore has been shipped.

In the Lead Hill mine on the north side of Salina Canyon about 4 miles east of Salina, lead and zinc sulphide ore occurs disseminated in the lower sandstone of the Flagstaff formation. Some ore was shipped from this property in the years 1908 to 1912, but it is now idle.

West Tintic district. The principal prospects in the West Tintic district are found in a small area at the extreme southern end of the Sheeprock Mountains. The area is marked by major thrusting, which has thrust Proterozoic quartzites and slates over folded Paleozoic limestone and dolomite, and by the intrusion of a series of monzonite, monzonite porphyry, granite, and aplite stocks and dikes. Contact metamorphism is prominent near the larger intrusions. Pyrometasomatic veins, mesothermal deposits, and low-temperature veins and replacements have all been identified with a great variety of mineral assemblages (Stringham, 1942, p. 268 and 281-287).

The author located no figures on the total production of the West Tintic district but high-grade lead, zinc, gold, and silver ore was shipped in the early years of its active life and some prospecting and development work has continued intermittently until only recently.

Iron

There are six minor occurrences of iron in the Sevier drainage: (1) in the Drum Mountains north of Joy, (2) at the northern end of the Beaver Lake Mountains in southern Millard County, (3) at Twin Peaks in Millard County, (4) in the Main Tintic district, (5) in the West

Tintic district, and (6) in the Antelope Range north of Marysvale. Only one of these occurrences, the Drum Mountain occurrence, has produced ore in the recent past. This deposit is operated by the Lynn Mining Company, and ore is shipped to the Marblehead Lime Company of Chicago.

The ore of the Drum Mountains is limonite which apparently occurs as a bedding replacement lense in limestone at its contact with underlying quartzite. The deposit in the northern end of the Beaver Lake Mountains consists of specular hematite and magnetite in white marbleized limestone near the contact of a quartz monzonite intrusion, and the Twin Peaks deposit is a limonite occurrence (Nackowski and Levy, 1959, p. 37-41).

In the Main Tintic district compact limonite ore containing from 55 to 57 percent iron was found in the Mammoth area and in the Iron Blossom mine (Butler et al., 1920, p. 415). Iron oxides were also mined at the Dragon mine before it became a halloysite producer and small amounts are still mined with the clay.

Some magnetite and specularite occur in pyrometasomatic veins with antimony in the West Tintic district. Limonite and hematite occur in mesothermal veins and replacement bodies in the same district (Stringham, 1942, p. 282-283).

The iron deposit in the Marysvale area occurs in a quartz latite body in the central part of the Antelope Range. The latite has been highly altered and the ore, which consists of yellow and reddish earthy hydrous oxide of iron, brown and black hydrous oxides of manganese and iron, and stalactitic masses of limonite, occurs in irregular fissures (Butler et al., 1920, p. 546). The Krotki mine was located at this occurrence and iron and manganese ore was shipped to local smelters (Crawford, 1943, p. 27).

Manganese

Crittenden (1951, p. 24-33, 35-36, 39-44) describes a number of manganese deposits within the Sevier River drainage. The author did not visit all of these deposits; therefore, a great deal of the information presented in the following summary was taken from Crittenden's descriptions.

Abraham Hot Springs deposit. At the eastern edge of a low lava plateau about 19 miles northwest of Delta, a hot springs deposit of manganese occurs. The manganese is apparently in lenticular layers interbedded with calcareous tufa. Although this deposit has been mined at times in the past it does not constitute a great potential source of manganese, for very little of the material from the deposit contains more than 15 percent manganese.

Detroit district. The Detroit district in the Drum Mountains has been one of the principal producers of manganese in Utah, producing almost two-thirds of the ore mined in the state since 1900. The manganese was originally deposited as rhodochrosite (Callaghan, 1939, p. 513). Part of the ore has been affected by surface and ground water, and most of the production has been from the resulting oxides.

The ore bodies are located near the intersection of major faults with dolomitic beds close to the base of the Cambrian carbonate succession. These bodies range in size from small ones a few feet in diameter to others that are 500 feet long and 50 feet wide. The grade of some of the oxide ore is as high as 48 percent manganese, but the average is about 20 to 25 percent. The carbonate ore averages about 15 to 25 percent manganese, but some contains as much as 40 percent.

Erickson district. The Erickson mining district is in the southern part of the Simpson Mountains on the boundary between Tooele and Juab Counties. It lies in an area of Cambrian quartzite, shale, and conglomerate which is cut by porphyry dikes and by numerous high-angle faults, along which manganiferous quartz veins have formed. These veins also contain small amounts of lead, silver, and zinc and were originally prospected for these metals.

The veins are irregular and generally narrow but in places they widen into pod-like bodies. From the surface to a depth of about 100 feet the ore is a cavernous mixture of quartz, altered country rock, and manganese oxides, while below the zone of oxidation the ore occurs as dense rhodonite and rhodochrosite.

Main Tintic district. Next to the Detroit district the largest manganese producing district in the Sevier drainage has been the Main Tintic district. Here many of the precious- and base-metal deposits contain traces of manganese, and some contain considerable quantities of low-grade manganese oxide. At least eight properties have shipped this ore and the total production of manganese ore from the district exceeds 8,000 long tons that averaged 24 to 25 percent manganese.

All of the production has been from manganese oxide deposits; however, it is assumed, but not demonstrated, that these oxides were derived from rhodochrosite or other primary manganese minerals (Pardee, 1921, p. 207).

Marysvale region. There is a group of six manganese deposits on the west slope of the mountains about 5 miles east of Marysvale.

These deposits are owned by Max Krotki and Dan Stocks of Marysvale. They were mined in the 1940's by the Combined Metals Reduction Company but are currently inactive. The ore occurs as veinlets of pyrolusite in a fractured flow breccia about 12 feet thick.

Manganese oxide occurs in Dry Creek Canyon about 10 miles southeast of Marysvale. The ore is in nearly vertical fissures cutting volcanic rocks. There may be a few thousand tons of ore in this area but the veins are very narrow and mining may not be practical.

About 14 miles east of Marysvale just north of the road to Manning Creek Canyon, there is a manganese deposit. Hard manganese oxide fills fractures for a width of about 5 feet on the footwall of a fault. The fault strikes east and dips 85° north and cuts massive andesite. The hanging wall is barren. It is reported that a carload of ore averaging 40 percent manganese was shipped from this deposit during World War II, but there appears to have been no recent development of this deposit.

Minor occurrences. In the Sevier River Canyon about 5 miles east of Leamington, manganese oxides occur at several horizons in Cambrian limestone and conglomerate. The author found no record of ore shipments from this area.

At the top of a ridge just east of Highway 28, 13 miles south of Levan, manganese occurs in veins cutting sandstone. The ore is described as braunite and a little psilomelane with a gangue of quartz and chalcedony. Samples tested by the U. S. Department of Interior, Bureau of Mines, showed a manganese percentage of from 6.4 to 9.3. To the west of this area, in low hills of interbedded sandstone, volcanic breccia, and rhyolite flows, a few narrow north-striking veins of manganese oxide with coarsely crystalline calcite have been located.

There are several minor occurrences of manganese in the vicinity of Monroe in Sevier County. Only one of these, the Georgia Mine, was visited by the author. The ore in this deposit occurs nearly parallel to the flow structure in andesite porphyry. Crittenden (1951, p. 36) reports that ore shipped from this mine in the years 1916 and 1918 had an average grade of 40 percent.

Mercury

Several hundred feet above the lower Deer Trail mines in the Marysvale region a north-trending, narrow, nearly vertical vein of barite and mercury was worked from 1881 to 1887 and again in the early 1900's. The mercury ore was low-grade onofrite and some tiemannite (the sulfoselenide and the selenide of mercury). In addition, small lenses of cinnabar were reported to occur with pyrite along bedding planes in the Deer Trail mines (McCaskey, 1912, p. 914).

Tungsten

There are two areas within the Sevier drainage where significant tungsten deposits occur: (1) in the House Range, and (2) in the West Tintic mining district. The House Range deposits occur in a tactite zone within gently dipping upper Cambrian limestone at or near the periphery of the Notch Peak quartz monzonite intrusion. The ore mineral is scheelite and the ore produced had an average grade of 0.2 to 0.3 percent WO_3, although higher-grade ore was produced at times (Nackowski and Levy, 1959, p. 74).

Several thousand tons of ore were produced in this area between 1941 and 1956. Since that time the operators of these properties have been unable to compete at world market prices and the properties have been closed down.

Scheelite also occurs in pyrometasomatic veins in the West Tintic district (Stringham, 1942, p. 281), but here there has been little production. Just prior to 1956 some attempt was made to develop these deposits under a federal price support plan; but when funds were not appropriated to purchase tungsten for the national stockpile in fiscal year 1957, the development work ceased (Utah Mining Association, 1959, p. 55).

Uranium

Uranium was first found in commercial quantities in the Ohio district shortly after World War II, and since that time the Marysvale area has become one of the leading producers of this metal in the state. Because of Atomic Energy Commission security classifications, total production and recent yearly production figures are not available; however, the Utah Mining Association (1959, p. 63) lists the 1956 yearly production as 41,529 tons. Nearly all current mining operations in the area are being conducted by the Vanadium Corporation of America, with the Farmer John, Freedom, and Prospector mines as the major producing properties.

The Antelope Range in which the uranium deposits are located is in a graben between the Sevier fault on the east and the Tushar fault zone on the west. In this graben both sedimentary rocks and Tertiary volcanic rocks were intruded by quartz monzonite and granite. All of these rocks were then eroded and on the erosion surface a second series of Tertiary volcanic rocks were extruded (Kerr *et al.*, 1957, p. 1-2).

The uranium mineralization was primary and originated in a second stage of hydrothermal activity following an earlier stage that produced the numerous masses of alunite in the area. It occurs primarily within the intrusions, where faults and fractures acted as channels for the hydrothermal solutions. The extent of the mineralization is controlled by the vertical extent of these faults. Zones of clay have formed along the veins as the result of wall-rock alteration and numerous prospects show patches of alteration (Kerr et al., 1957, p. 60).

In addition to the Marysvale uranium deposits, uranium deposits have been developed on the west side of the Thomas Range. Here oxidized uranium minerals occur in volcanic rocks (Nackowski and Levy, 1959, p. 100).

Summary

A number of valuable metallic mineral deposits are located within the Sevier River drainage. Although most of the mining districts are now almost entirely inactive in regard to metal production, some still have great potential. In most areas the mineral reserves were not depleted and a more favorable market would undoubtedly result in renewed production. In addition, a modern concentrated exploration program similar to that being conducted in the East Tintic district by the Bear Creek Mining Comparny, a subsidiary of Kennecott Copper Corporation, might result in a complete revival of some of the districts.

The occurrence of a highly varied economic mineral assemblage in the West Tintic district presents a potential for further development. Significant upward changes in the market prices paid for any one of the major metals occurring in the district might justify additional exploration and development work.

Attempts to further develop gold and silver deposits in the Ohio and Kimberly districts have met with little success. One of the major problems encountered, in addition to high mining costs, has been the establishment of a market for the ore because of its low grade and its association with silica gangue. It is possible that continued exploration in these districts will result in new discoveries of higher-grade deposits, and there is some indication that the property now being developed near the mouth of Bullion Canyon will stimulate more extensive exploration.

Although manganese is rather common in occurrence throughout the Sevier River drainage, only the deposits in the Erickson, Detroit, and Main Tintic districts have any great potential with the market at its current low level. Some of the other deposits contain manganese ore in sufficient amounts and grade to warrant future consideration, however.

Uranium production from the Marysvale deposits should continue to be an important part of the metals industry of the region. The deposits of the Thomas Range are of lesser importance but continued development work may result in the location of more extensive deposits.

At the present time there is a great demand for beryllium. The western part of the Sevier River drainage should continue to be considered as one of the state's most important potential sources of this metal.

NON-METALLIC MINERALS AND ROCK PRODUCTS

General Statement

At the present time the production of non-metallic minerals and rock products is much greater than the production of metals in the Sevier River drainage. A number of the larger occurrences are currently being exploited. The gypsum, Fuller's earth, and bentonite of Sevier County, the halloysite of the Main Tintic district, the alunite of the Marysvale region, and the salt of Sanpete County are probably the most important of these. A number of smaller operations exist also, including several important sand and gravel operations, and there are some undeveloped occurrences that show promise.

Non-metallic Mineral and Rock Occurrences

Alunite

In the Marysvale area there are extensive deposits of alunite. Estimates of the total reserve made by the U. S. Department of the Interior, Bureau of Mines, run as high as 30,000,000 tons (Utah Mining Association, 1959, p. 64). The only mining at the present time is being conducted by the Calunite Corporation. This corporation maintains a crushing plant at Marysvale and makes regular shipments of alunite for use as fertilizer.

The mineral occurs both in veins and in replacement bodies. In the Little Cottonwood Canyon area, about 7 miles southwest of Marysvale, the alunite occurs in large veins cutting altered dacite and andesite

(Butler, 1912, p. 6). Loughlin (1916, p. 240-241) describes the veins as occurring in three nearly parallel zones trending north to northwest with dips generally 50° to 70° west and describes three separate varieties: coarsely crystalline, fine-grained to dense, and laminated, with the coarsely crystalline variety as the most common. The color ranges from pink to white.

Butler (1912, p. 8) gives the following chemical analyses of alunite from this area:

	Percent	Percent
Al_2O_3	37.18	34.40
Fe_2O_3	Trace	Trace
SO_3	38.34	36.54
P_2O_5	.58	.50
K_2O	10.46	9.71
Na_2O	.33	.56
H_2O+	12.90	13.08
SiO_2	.22	5.28

Extensive hydrothermal alteration in the area around the intrusions of the Antelope Range has also produced large alunite deposits. The alunite occurs in pyroxene andesite and tuff of the older volcanic rock series, the Bullion Canyon series (Kerr _et al._, 1957, p. 1). The White Horse deposit from which the Calunite Corporation now quarries much of its alunite (Plate 2; Figure 1) is one such replacement deposit. The ore occurs in three main bodies and several smaller bodies with a thick envelope of partly kaolinized rock surrounding each body (Willard and Proctor, 1946, p. 619). These replacement bodies consist primarily of the fine-grained variety of alunite.

Plate 2.

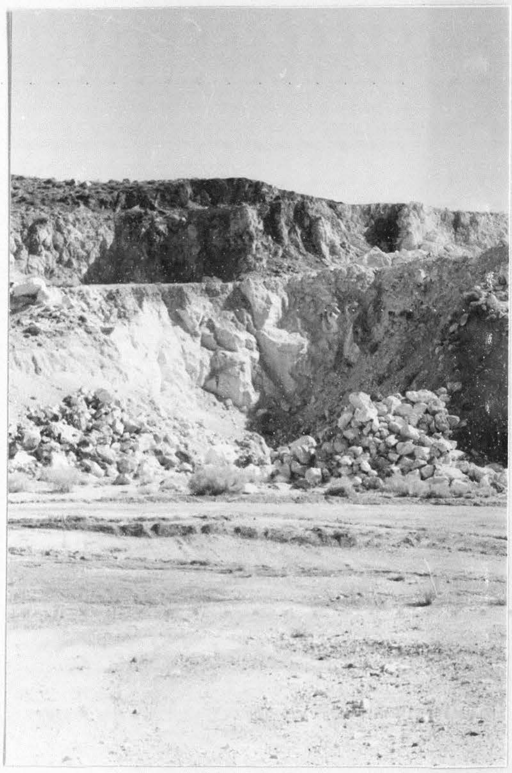

Figure 1. White Horse alunite quarry east of Marysvale

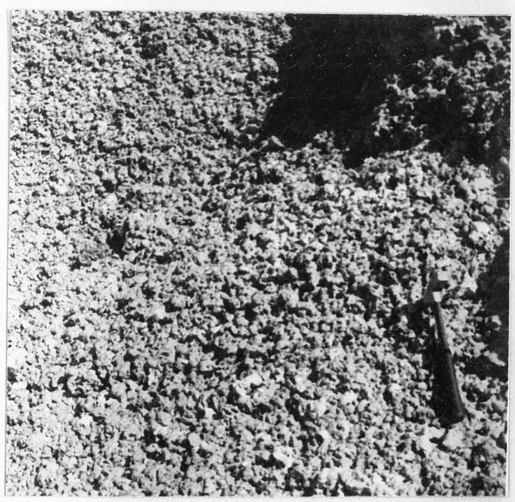

Figure 2. Wet bentonite in deposit west of Redmond

The extensive Marysvale alunite deposits have long challenged development. As early as 1916 studies were made on the recovery of potash from this material (Waggaman and Cullen, 1916), and during World War I alunite was mined for this purpose. During World War II mining activity was revived, and experimental attempts were made to extract alumina, potash, and sulfuric acid from alunite mined in this area (Hild, 1946, p. 3). Successful processes were devised to accomplish this extraction, but none have proven to be economical.

Aragonite and calcite

There are several aragonite and calcite veins in the Sevier drainage that might be of commercial value. Possibly the most important of these are in the Salina area, in the Valley Mountains west of Gunnison, in the area between Nephi and Leamington, and northwest of Cove Fort.

As described above, there are a number of normal and thrust faults in the Salina area that show mineralization. Nearly all of these contain calcite and are commonly pure calcite (Spieker, 1949, p. 53). In the past some of these veins have been mined, and in the mouth of Salina Canyon, a calcite mill once existed. At the present time there are no active properties in the Salina area, however.

In the Valley Mountains and at the base of the Tushar Mountains near Cove Fort there are a number of large calcite veins. All of these are undeveloped.

The only active properties are located in the hills southwest of Nephi, where several large aragonite veins cutting limestone are mined and transported to Nephi for crushing. The crushed product is sold as poultry grit and for use in the building trades.

Asbestos

Only one minor occurrence of asbestos is reported within the Sevier drainage. This occurrence is located at the northern end of the Mineral Range in southern Millard County and is described by Nackowski and Levy (1959, p. 98) as coarse-grained radiating fibrous tremolite occurring in marble.

Barite

In the West Tintic district quartz-barite veins, generally containing some galena, are abundant. The veins vary from a fraction of an inch to 3 or 4 feet in thickness. They occur in Paleozoic sedimentary rock surrounding a monzonite intrusion and beyond the zone of contact metamorphism. Most of the veins have been worked for their galena content, but little of the ore has been shipped (Stringham, 1942, p. 284-285). Nackowski and Levy (1959, p. 98) also report a minor barite deposit in the extreme northern part of the Mineral Range in southern Millard County.

Bentonite

In the Sevier Valley, just west of Redmond, two small hills of bedrock protrude from the alluvium of the valley. These hills are formed of Tertiary pyroclastic and sedimentary rocks which overlie vertical Arapien shale and contain large bentonite deposits (Plate 2, Figure 2, page 21; Plate 3, Figures 1 and 2). No estimate of the total reserve in these deposits is available; but two companies, the Redmond Salt and Clay Company and the Western Clay and Metals Company, have active mining operations in the area. The Redmond Salt and Clay Company recently opened a small plant in Redmond, while the Western

Plate 3.

Figure 1. Bentonite beds in hill of Arapien shale west of Redmond

Figure 2. Western Clay and Metals Company bentonite quarry

Clay and Metals Company maintains a plant in Aurora where bentonite and Fuller's earth are processed and shipped.

Gilliland (1951, p. 49) describes the dominant minerals of the bentonite as undifferentiated members of the montmorillonite group that are, for the most part, the result of devitrification and alteration of minute shards of volcanic glass, but are also the result of partial alteration of many felsitic and glassy rock fragments. Some feldspar and biotite are also altered.

Sedimentary beds containing bentonite are exposed on the west side of the valley near Richfield. These beds are Tertiary in age and are overlain by the Dry Hollow series of latitic tuffs, latites, and basalts also of Tertiary age (Gilliland, 1951, p. 50).

Building stone

The Green River formation of Eocene age, which is exposed on the western flank of the Wasatch monocline, in the vicinity of Round Valley, and in the Gunnison Plateau area, locally contains oolitic limestone beds that are of value as building stone. These beds occur in the tan upper limestone member which varies in thickness from 100 to 400 feet (Spieker, 1949, p. 35).

In the past this rock was quarried and used extensively for local building in the Manti-Ephraim area. The best example of this is the Manti Temple, one of the most impressive buildings in the state, which was built from oolitic stone quarried in the immediate vicinity. Northwest of Ephraim another quarry was once operative and from this quarry some of this stone was shipped beyond the local area.

Some sandstone and travertine have been produced in Millard County for ornamental and building purposes. A travertine quarry between Fillmore and Meadow produced small quantities in the late 1940's, but there is no record of commercial production since that time (Utah Mining Association, 1959, p. 61).

At the base of the Canyon Range due west of the Sevier Bridge Reservoir, building stone has been quarried from an outcrop of red flagstone of Cretaceous age. This bed of flagstone is about 25 feet thick and dips gently to the west. Only small amounts of stone have been quarried at this deposit recently.

Coal

The only significant coal occurrences located within the Sevier drainage are in Sanpete and Sevier Counties. These deposits were first developed during the early years of Utah history but are nearly all inactive at the present time.

Coal occurs in Salina Canyon in the upper member of the Blackhawk formation. Spieker (1927, p. 149) reports that there are 18 separate beds of coal which range in thickness from 5 inches to 10 feet but that half of these are less than 1 foot thick and that only two are greater than 6 feet thick. Possibly the most valuable of these coal beds has been located near the bottom of Salina Creek at the uppermost limit of the canyon. This bed is believed to be the same as the most valuable bed of the Ivie Creek district on the Wasatch Plateau and to contain, in this area alone, 140,000,000 tons of coal (Spieker, 1927, p. 150). This tonnage estimate is based on the assumption that the bed underlies at least 30 square miles in the upper Salina Canyon area.

Test drilling by the U. S. Department of the Interior, Bureau of Mines, has located coal beds in the Blackhawk formation east of

Mt. Pleasant. Five beds, ranging in thickness from 2 feet to nearly 6 feet, were found at a depth of from 1,700 to 2,000 feet. The coal was interbedded with gray shale, carbonaceous shale, and fine-grained sandstone (Duncan, 1946).

An oil and gas test drilled in Sanpete Valley also penetrated coal beds in the Blackhawk formation. In this area, however, the coal lies at a depth too great to be of any economic value at the present time.

Near the base of the eastern flank of the Gunnison Plateau west of Wales, two coal horizons occur within the North Horn formation. The lower horizon contains bituminous coal of irregular thickness. The thickness ranges from 1 to 5 feet. The upper horizon contains only thin lenses of coal interbedded with carbonaceous shale and are of no economic value (Clark, 1912, p. 478). The lower horizon is apparently continuous from north of Wales Canyon to Coal Canyon and a short distance beyond, but southward the lithology of the North Horn changes rapidly and the coal beds apparently pinch out.

The Indianola group contains coal beds at exposures in the Sterling-Manti area. Here several coal beds with a maximum thickness of only a few feet are interbedded with sandstone. The coal is bituminous and dark in color, but it has numerous calcium carbonate filled joints running through it in all directions, causing the coal to break easily (Richardson, 1906, p. 283). An analysis of coal from this area as well as the other areas of the Sevier drainage is presented in Table 1.

Table 1. Analyses of coal from the Sevier River drainage

Analysis of coal	Wales area[a]	Salina Canyon area[b]	Sterling-Manti area[c]
	percent	percent	percent
Moisture	2.17	14.94	8.07
Fixed carbon	50.94	40.37	43.20
Volatile combustible	33.50		42.59
Volatile material		36.25	
Ash	13.39	8.44	6.14
Sulfur	4.62	0.41	0.92
Air-drying loss	0.80	11.20	1.80
Fuel ratio	1.52		1.01
Heating value (in calories)		5383	6537

[a](After Richardson, 1906, p. 283)

[b](After Spieker, 1927, p. 164)

[c](After Richardson, 1906, p. 284)

Diatomaceous earth

Only two deposits of diatomaceous earth have been located in this area. One of these occurs at the southern end of Sevier Lake and was considered by Nackowski and Levy (1959, p. 99) to be of minor importance. The other deposit, also of minor importance, was described by Wimber and Crawford (1933, p. 61) as a 3-foot thick, non-commercial Tertiary bed. This bed is located in Sevier County near the intersection of Highway U. S. 89 and State Highway 13.

Fluorite

There are four major fluorite districts in Juab County, including the Spors Mountain district which is the largest producing fluorite district in the state of Utah (Nackowski and Levy, p. 23-24). Only two of these, the Spors Mountain district and the West Tintic district, are within the Sevier River drainage, however. In addition to these Juab County deposits, fluorite occurs in the Marysvale area and in a single deposit about 1½ miles northwest of Cove Fort in Millard County.

Spors Mountain, the western branch of the Thomas Range, is composed of Paleozoic quartzite and overlying dolomite which have been complexly faulted and intruded by numerous plugs and dikes. The fluorspar deposits are epithermal pipe-like bodies or veins occurring in the dolomite and the intrusive rock but not in the quartzite. Most of the production has been from the irregular pipe-like bodies. These bodies range in size from small ones 15 feet in diameter to one that is 176 feet long and 103 feet wide, and they are commonly associated with faults. The fluorite itself is white to deep-purple and constitutes 65 to 95 percent of each deposit. Clay minerals, dolomite, calcite, carnotite, quartz, and opal also occur in minor amounts (Thurston et al., 1954, p. 26-28).

In the Rain Bow mine northeast of Cove Fort, fluorite occurs as crystalline white, green, pale amber, or purple aggregates filling fractures in Paleozoic limestone (Nackowski and Levy, 1959, p. 36). In the West Tintic district colorless to purple fluorite occurs in considerable amounts in the "88" mine and is associated in a vein deposit with quartz and galena (Stringham, 1942, p. 285).

There are two separate occurrences of fluorite in the Marysvale area. It occurs as a minor mineral in fracture filling quartz veins cutting quartzite and lava in the Bulley Boy and Webster mines of the Ohio district (Butler et al., 1920, p. 556). It also occurs in steeply dipping fissure fillings and breccia zones at the Farmer John, Freedom, and Prospector uranium mines (Thurston et al., 1954, p. 50-51).

The only district in which fluorite is currently being mined as a primary ore is the Spors Mountain district. The reserves in this district were reported in 1950 to include 62,000 tons of indicated ore and 300,000 tons of inferred ore (Nackowski and Levy, 1959, p. 30).

Fuller's earth

This commercial clay is being mined $1\frac{1}{2}$ miles northwest of Aurora and is processed at a mill in Aurora and shipped by the Western Clay and Metals Company. The Fuller's earth bed overlies clay and sandstone which are probably Cretaceous in age and grades upward into tuff and agglomeratic tuff (Crawford and Cowles, 1932, p. 56-57). It strikes north and dips about 20° east, has an average thickness of about 40 to 45 feet, and has been mined along its strike for more than one-half of a mile (Plate 4). Crawford and Cowles (1932, p. 56-60)

Plate 4.

Figure 1. Fuller's earth quarry of the Western Clay and Metals Company northwest of Aurora

Figure 2. View looking north from Western Clay and Metals Company quarry along strike of Fuller's earth beds

indicate that this clay is composed primarily of decomposed dacitic breccia which may have been altered by hot gases either before or after deposition.

Gem minerals

The important gem mineral occurrences of the Sevier drainage are listed below. Bixby's Catalogue of Utah Minerals and Localities (Bixby, 1959, p. 1-32) was the principal source of information used in preparing this list. Most of these gem minerals are of the semi-precious type and are of interest to the lapidary particularly.

Alabaster. This massive granular gypsum occurs in brownish and yellow tints within the Arapien shale near Levan.

Amethystine quartz. This gem variety of quartz can be found in the foot hills east of Marysvale.

Beryl. The occurrences of beryl in this area were described above in the description of the metallic mineral deposits.

Chalcedony. Chalcedony in geodes can be found in the Thomas Range, the southern part of the Dugway Range, and the foot hills northeast of Glenwood in Sevier County.

Corundum. This mineral occurs locally in angular masses near the southern end of Sevier Lake.

Garnet. Garnet occurs in the rhyolite and loose sandy debris of the Thomas Range and the Dugway Range.

Jasper. Jasper has been reported in the Drum Mountains in considerable abundance.

Mexican onyx. Mexican onyx occurs in the hills west of Redmond (Gilliland, 1951, p. 11).

Obsidian. Red and black spherulitic obsidian, as well as other varieties, occur near Black Rock in Millard County.

Topaz. Topaz occurs in the Dugway and Thomas Ranges, particularly in the vicinity of Topaz Mountain.

Gypsum

The gypsum deposits in the vicinity of Sigurd, and in several other localities, are the area's most extensive commercial mineral deposits. The reserve of high-grade gypsum in the Sigurd area alone is estimated to be nearly 12,000,000 tons (Utah Mining Association, 1959, p. 81), and there are additional commercial deposits in the Nephi-Levan area, and in sand dunes east of Meadow in Millard County.

The only large scale exploitation of these deposits is being conducted by the U. S. Gypsum Company and the Bestwall Gypsum Company. Both of these companies mine rock, which averages 98 percent $CaSO_4$ and 2 percent water (Hardy, 1952, p. 61), by open-pit methods (Plate 5, Figure 1) in the area between Salina and Sigurd. The combined production of these two companies from plants in Sigurd is approximately 200 million square feet of wallboard and lath per year plus large quantities of plaster, raw gypsum, and calcined gypsum that is used for pottery, dental and orthopedic plaster, industrial molding, and building products (Utah Mining Association, 1959, p. 81).

A smaller mining operation is active southeast of Levan. The Cox Brothers' Construction Company of Manti quarries gypsum in the vicinity of Deep Creek Canyon and ships the ore from the railroad siding of Juab.

The gypsum beds both in the Sigurd area and in the Nephi-Levan area occur in the lower part of the Jurassic Arapien shale (Hardy,

Plate 5.

Figure 1. Gypsum quarry northeast of Sigurd

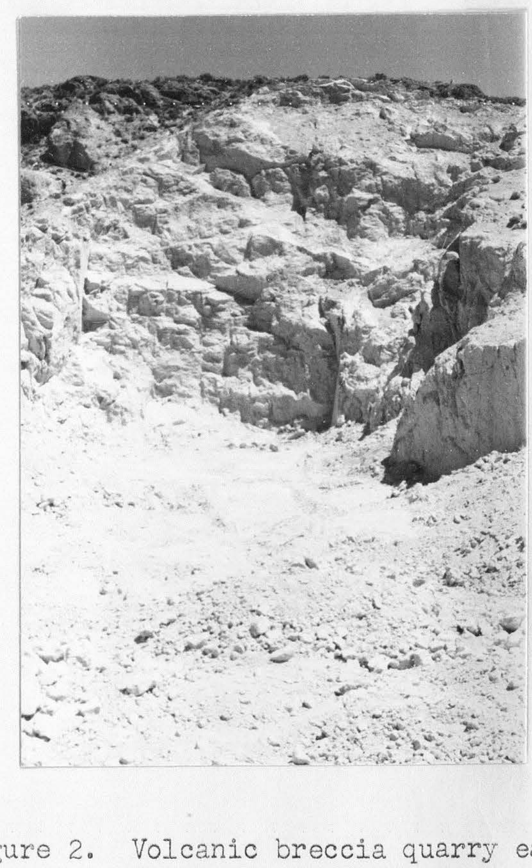

Figure 2. Volcanic breccia quarry east of Sevier River bridge

1952, p. 61). In the area between Fillmore and Meadow, the gypsum occurs in nearly pure gypsum sand dunes and in gypsiferous clay (Adams _et al._, 1904, p. 107).

In the Sigurd area the gypsum generally occurs in lenses exposed in northwest-trending en echolon piercement folds (Bell, 1953, p. 1541). Bell further postulates that the dislocation of the gypsum which resulted in the formation of these extensive lenses of commercial-grade gypsum is related to these folds and is the result of decollment folding of the mobile Arapien shale above competent underlying rocks during the Laramide orogeny.

In the discontinuous belt of Arapien shale exposed on the western side of the Gunnison Plateau in the vicinity of Nephi and Levan, the gypsum also occurs in thick lenses. Christiansen (1949-1950, p. 87) also attributes this to local thickening and thinning of the gypsum beds as a result of Laramide folding, with the force involved in this dislocation locally disrupting the continuity of the folds.

The gypsum of the Millard County deposits was transported by streams from the mountains on the east and redeposited with detritus in the White Mountain playa. Much of it was later freed from the associated sediments and reconcentrated by the wind (Adams _et al._, 1904, p. 107).

Halloysite

The production of halloysite in the Main Tintic district has become the most important mining operation in Juab County. Over 750,000 tons of this clay have been mined and shipped from this district by Filtrol, Inc. since 1949, and the remaining reserve was estimated in

January 1961 to be nearly 500,000 tons (personal communication from Leonard Ryan, mine supervisor).

The Dragon halloysite mine is located near the northeast corner of a monzonite stock in the Main Tintic district. The clay occurs with pyrite and iron oxide as a hydrothermal replacement, chiefly in the limestones of the upper Cambrian Ajax formation and the lower Ordovician Opohonga formation. It has been postulated that this replacement was due to hydrothermal solutions rising along northeast-trending fissures and becoming trapped under overlying igneous rocks (Kildale, 1957, p. 94-95).

Halloysite also occurs with kaolinite and montmorillonite in altered sills and dikes in the Drum Mountains north of Joy, and in the southern Thomas Range (Nackowski and Levy, 1959, p. 98). These deposits are of only minor importance.

Limestone and dolomite

Near the Millard County-Juab County line about 6 miles east of Leamington, Cambrian and Ordovician limestone and dolomite are quarried from nearly vertical beds. The production of these quarries is not great at the present time, but shipments are still made occasionally. Rock shipped from this quarry is used primarily as a flux in smelting operations.

Along the flanks of the Cricket Mountains low silica limestone and dolomite of middle Cambrian age have been mined in the past. During the period 1947-1950, shaft kilns were cut in the limestone and fired with cedar. The burned lime was sold for use in the building trades. Production declined after this period. More recent mining has been confined to a 70,000 ton test lot in 1958 (Nackowski and Levy, 1959, p. 49).

The Poulson Brothers' Salt Company of Redmond have limestone properties in Willow Creek Canyon east of Axtell. From these properties limestone for use by the sugar factory at Centerfield is produced.

A limestone quarry east of Robinson in the Main Tintic district has been operated intermittently in the past. This quarry is in the Teutonic limestone of Cambrian age.

Oil shale

On the western flank of the Gunnison Plateau near Chase Creek Canyon, oil shale beds are exposed. This oil shale is interbedded with thinbedded sandstone within the Green River formation. The beds have apparently been displaced by several eastward-trending faults and are exposed at several horizons. The greatest exposed thickness examined by the author was about 80 feet of oil shale and sandstone. A still was constructed in this area in the early 1900's and attempts were made to extract oil from these rocks, but there has been no recent attempts to develop this deposit.

Salt

In the Arapien shale of the Sevier Valley north of Redmond, there are thick salt beds which are currently being mined. These beds have a vertical attitude (Plate 6, Figure 1) and have a total thickness of from 800 to 1,000 feet (personal communication from Albert Poulson).

The Poulson Brothers' Salt Company, the Albert Poulson Salt Company, and the recently organized Redmond Salt and Clay Company, all of Redmond, have active operations in this area. Approximately

Plate 6.

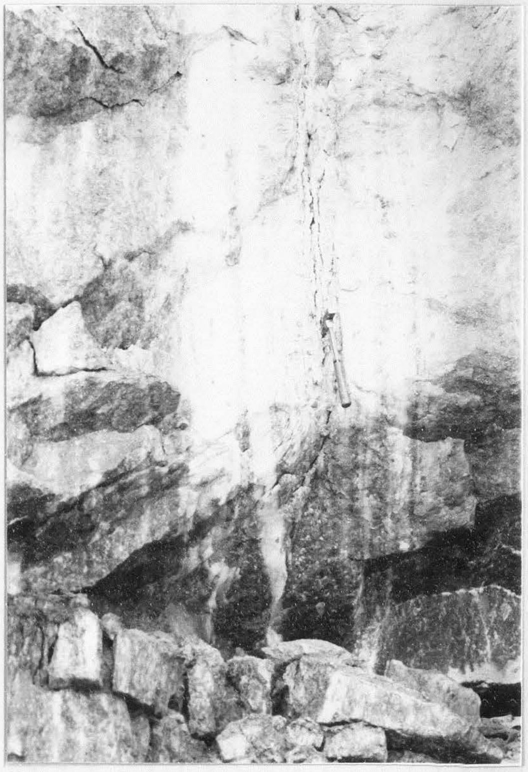

Figure 1. Vertical salt beds in the Arapien shale northeast of Redmond

Figure 2. Poulson Brothers' salt quarry northeast of Redmond

8,000 tons of block and crushed salt were shipped in 1960 for livestock consumption. The salt is quarried, after a clay overburden of 25 to 30 feet is removed (Plate 6, Figure 2), and hauled by truck to Redmond to be crushed and screened or shipped in block form.

The following analysis of salt from the Redmond area has been reported by Gilliland (1951, p. 61):

	Percent
Salt, NaCl	95.60
Silica	2.16
Sulphates	1.10
Calcium	0.51
Iron and alumina oxides	0.04
Manganese	0.04
Iodine	0.03

On the east side of the valley, east of Redmond, there is an additional salt bed in the Arapien shale. This bed once was mined by the Great Western Salt Company, but the high clay content of the bed prevented its full development.

There are also salt beds in Salina Canyon and in Salt Creek Canyon, east of Nephi, where the Arapien shale is exposed. There is no attempt being made at the present time to work these deposits, however.

Sand and gravel

There are a great number of sand and gravel deposits within the Sevier River drainage. Possibly the most important of these in terms of present production are: the large deposit in Centerfield, which is owned and operated by Marwood Hale of Redmond; the deposit of the Johnson Sand and Gravel Company at the southeastern edge of Ephraim; the deposit worked by the Ferrell Adams and Sons Redi-Mix Company at

Fillmore; and the operations of Elmo Herring in Richfield. Substantial operations are being conducted at all of these deposits at the present time. In addition there is an active operation in Chicken Creek Canyon, east of Levan, where the Juab County Road Commission is removing limestone talus for use in road construction.

There are other deposits which are being developed less fully south of Nephi, north of Mt. Pleasant, in Twelvemile Canyon near Mayfield, west of Redmond, and in many other localities. These deposits supply local building and road construction needs.

Silica

Outcrops of the Tintic quartzite near Eureka, west of Jericho, and east of Leamington have been mined as commercial-grade silica deposits. At Jericho a crushing plant owned by the General Refractories Company is still operating intermittently.

Major quartz veins in the Moroni area and in Sevier County about 4 miles south of Monroe show some promise as silica deposits (Utah Mining Association, 1959, p. 82). These are not currently being developed, however.

Sulfur

There are two known sulfur deposits in the vicinity of Cove Fort. The most important of these is the Sulfurdale deposit. Olsen and Williams (1960, p. 10) describe this deposit as small pods, stringers, and disseminated grains of sulfur in alluvium and sinter and indicate a reserve of 8,000,000 tons of ore with an average grade of 25 to 30 percent. The deposit is a hot springs deposit.

The deposits northeast of Cove Fort have been described by Nackowski and Levy (1959, p. 64) as elemental sulfur and marcasite which have been deposited by the action of hot springs in horizontal beds of volcanic tuff. The elemental sulfur occurs above the water table as disseminated grains, in veins, and in masses of pure yellow sulfur or dark crystalline sulfur. Below the water table the sulfur ore occurs as marcasite.

No estimates of the reserve in the deposits northeast of Cove Fort were obtained. These deposits are owned by the American Sulfur and Refining Company, but there has been little attempt made to develop them.

Volcanic rock products

Breccia. Aumco, Inc., of Sterling, is currently quarrying volcanic breccia east of the Sevier Bridge Reservoir. The material is first crushed at the quarry then trucked to Sterling where it is further crushed, screened, and bagged. The final product is sold under the trade name Axomite for use as poultry grit and as a soil conditioner.

A partial analysis of this material received from Aumco, Inc. is as follows:

Element	Percent
Silica	51.00
Aluminum	6.20
Manganese	0.005
Potash	0.001
Calcium	1.00
Iron	0.01
Sodium	0.05
Fluorine	0.05

The breccia contains a high concentration of uncollapsed pumice fragments and pebbles of volcanic rock in a groundmass high in feldspar, quartz, and glass. It overlies a very coarse-grained sandstone unit which contains pebbles of volcanic rock similar to those in the breccia, and in some exposures it is overlain by rhyolite flows.

The total thickness of this material was not measured. It is the principal rock type in the low hills in the area east of the Sevier Bridge Reservoir and in one quarry a thickness of about 150 feet has been worked. Other small quarries have located in the area also.

Perlite. There are two deposits of commercial perlite in Millard County, the Huntsman perlite deposit and the Utah Pumice and Perlite Company deposit. The Huntsman deposit is about 23 miles west of Kanosh and consists of light-gray perlite, black perlite with numerous obsidian inclusions, and some perlitic agglomerate with a high ash content.

White to light-gray perlite and pumice are interlayered at the Utah Pumice and Perlite Company properties. These properties are located 6 miles east of Black Rock and include a Cudahy Mine (Nackowski and Levy, 1959, p. 88). Perlite from these properties has been shipped in recent years, but they are now inactive.

Pozzolan. The U. S. Department of the Interior, Bureau of Reclamation, located five natural pozzolan occurrences within the Sevier River drainage during a search for possible sources of pozzolan for use in the Glen Canyon and Flaming Gorge dams (Nackowski and Levy, 1959, p. 90-91). The only one of these occurrences that has great commercial potential is located just south of the Clear Creek Canyon road in southern Sevier County. This occurrence consists of extremely fine white unconsolidated volcanic ash.

Particle size analyses of material from this area were made by the author. The results of these analyses are shown in Table 2.

Table 2. Particle size analyses of volcanic ash from Clear Creek Canyon

Particle size	Percent by weight	
	Sample 1	Sample 2
Greater than 80 mesh	2.23	1.83
Less than 80 mesh; greater than 115 mesh	2.66	2.74
Less than 115 mesh; greater than 170 mesh	9.90	10.30
Less than 170 mesh; greater than 250 mesh	20.77	20.51
Less than 250 mesh; greater than 300 mesh	25.75	27.19
Less than 300 mesh	38.55	37.43

The ash is exposed on the south side of an east-trending valley near the northern end of the Tushar Mountains. It apparently occurs in a single bed that may be highly faulted. The bedding within the ash is unrecognizable, but welded tuffaceous material immediately underlying the ash dips to the south 20 to 25 degrees. A horizontal extent of 2,600 feet has been measured along the outcrop of the bed (personal communication from N. F. Nielson, part-owner).

Before true thickness measurements or an accurate estimate of the reserves can be made, some stripping and test drilling will be necessary. The bed was probably deposited across this entire small valley with the northern extension of the deposit later removed by erosion.

Projection of the bed from its exposures near the valley bottom to the mountain face to the south is, therefore, probably justified. If the dip of the bed is as great as the underlying rocks indicate, all of the ash bed would not be economically mineable because of thick overburden. The particle size, purity, and extent of this deposit seem to justify its development.

Pumice and pumicite. In the vicinity of the Cudahy mine in Millard County, there are extensive layers of pumice and pumicite. The variable nature of these layers and the interlayering with perlite make mining difficult, but Utah Lavalite, Inc. has developed a major operation in this area. The material produced is used in cleansing and scouring compounds, in the manufacturing of hand soap, and as an abrasive (Nackowski and Levy, 1959, p. 94-95).

Volcanic cinder. A zone of cinder cones which extends in a north-south direction across the center of Millard County presents a great potential for the production of commercial cinder. The Flowell cinder cone, located about 9 miles west of Fillmore, has become a large-scale producer. The material is used primarily as an aggregate for concrete and concrete products.

In 1956 more than 40,000 tons of cinder were mined at the Flowell cone. Since that time production has decreased to some extent, but it is still a very significant part of the mining industry in Millard County (Nackowski and Levy, 1959, p. 81).

Summary

Gypsum, halloysite, bentonite, Fuller's earth, sand, and gravel are the most important of the non-metallic minerals and rock products of the Sevier River drainage. These commodities are important not only in regard to present production, but their extensive occurrences and accessibility present the greatest potential for even further development.

The production of salt in the Redmond area should continue to be an important part of the non-metallic industry of this region. The companies currently operating in that area apparently have well-established markets for the quantity of salt they produce, but the competition with the producers of salt in the Great Salt Lake region and the poorer quality of the Sevier Valley deposits seem to preclude much increased development.

The largest known fluorspar reserves in the state are in the Spors Mountain district. Further growth of the fluorite industry will, however, require a favorable change in the prices paid for this commodity.

The full development of the alunite deposits in the Marysvale area is almost entirely dependent on the development of an economical process for the extraction of alumina and potash from this material. Production of this mineral for use as a fertilizer should continue, but its market is restricted.

The recent trend toward more extensive use of calcite and aragonite in crushed form for building and landscaping might provide a more favorable market for these products and stimulate more active development of the larger and more accessible of the deposits in the Sevier drainage. These products are now being used extensively as roofing material, and in some areas, particularly in the arid parts of the western states, they are used in place of grass in landscaping around buildings and homes.

The completion of a sulfuric acid plant now planned by the American Sulfur and Refining Company to process sulfur from the Cove Fort-Sulphurdale area would undoubtedly result in extensive expansion of sulfur mining operations in that area. The extent and grade of the deposits justifies development of this kind.

In Millard County the production of volcanic rock products should continue to be an important part of the mining operations of the county. Increased and sustained production is assured by extensive reserves of pumice, pumicite, and volcanic cinder in particular. The volcanic ash occurrence in Clear Creek Canyon, near the Piute-Sevier County line, warrants consideration not only as a source of pozzolan but as a possible source of a base for cleaning and scouring compounds as well.

The coal reserves of the Sevier drainage are of lesser importance than reserves in other parts of the state, but an increased demand for coal as a source of petrochemicals in future years might revive interest in these deposits. The coal in the Salina Canyon area is of greatest importance because of its extent.

The oil shale deposit is probably of little value at the present time. Future expansion of extraction facilities may stimulate prospecting and development of oil shale in the Green River formation, but at present there is little justification for such interest.

No where within the Sevier drainage does transportation present a serious problem in the development of the mineral deposits. This factor further increases the value of a number of the occurrences.

GROUND WATER

General Statement

An extensive four-year study by the Ground Water Division of the U. S. Geological Survey is now near completion. Richard A. Young and Carl H. Carpenter have done a great deal of this work and they are currently completing a report that will be published as a U. S. Geological Survey water supply paper.

In a preliminary report on this study Young and Carpenter (1961, p. 1-6) state that there are about 1,738,000 acre-feet of water in the ground-water reservoirs of central Sevier Valley, but that the surface-water and ground-water systems are in equilibrium. Any development of ground water will have a definite affect on the amount of surface water available to water users further down the river. As water is removed from the ground-water storage surface water will begin to recharge the reservoirs from which the water was removed. Young and Carpenter point out, however, that development of ground water will result in the drainage of low wet areas and the eradication of large areas of low economic phreatophytes. This will provide a larger amount of ground water for beneficial use by reducing evapotranspiration losses.

In addition to this study, the U. S. Geological Survey has just begun a similar study of the Sevier Desert and surrounding areas. A regional office has been established at Delta for this purpose.

Significant differences between the occurrences of ground water in the eastern and western parts of the Sevier drainage were recognized by the author; therefore these region will be considered separately. The eastern region here described includes that area drained by the Sevier River as it flows northward, while the western region includes the Sevier Desert and adjacent areas and the Sevier Lake area.

Eastern Region

Unconsolidated sediments are the principal source of ground water in this region. Richardson (1907, p. 24) reports that beds of sand and gravel ranging in thickness from a few inches to many feet are widespread horizontally and occupy a great vertical extent in the valley fill of Sanpete and central Sevier Valley. These beds are separated by clay beds of varying thickness, which in many cases form aquicludes for artesian systems. This is especially true of the area just east of Richfield and in the area near Ephraim and Manti, for in these areas artesian wells have been located. These wells are used primarily for livestock supplies and little is used for irrigation. In other areas attempts to locate artesian wells have met with less success because of the irregularity and lenticular nature of the sand and gravel aquifers.

In addition to these unconsolidated sediments, there are some bedrock units which contain appreciable amounts of water in this region. These are primarily Cretaceous sandstone and conglomerate which in general dip toward the valleys from the western flank of the Wasatch monocline and in some localities from the highlands to the west (Richardson, 1907, p. 22). These rocks, where overlain and underlain by impervious rocks, provide a potential artesian system; but in many areas, especially in southern Sevier County, the system is disrupted by faulting at the base of the monocline. In other areas water-bearing rocks underlie the valleys at such great depths that their development is uneconomical (Richardson, 1907, p. 22).

East of Ephraim a well was drilled in search of water-bearing bedrock on the flank of the Wasatch Plateau. The well was dry. This may reflect an additional unfavorable condition to be considered in attempting to locate water-bearing rocks in this region. In Sixmile Canyon east of Sterling the Cretaceous rocks underlying the Flagstaff formation, which forms the cap of the Wasatch Monocline, have an east dip near the unconformable contact with the Flagstaff. Water movement in the beds near this contact would then be away from the valley. In the Ephraim well the water-bearing beds may have had a similar attitude and were, therefore, dry.

Springs are abundant in this region. Richardson (1907, p. 58-60) lists and describes 88, of which 33 are classified as fault springs and the remainder as seep springs. The water source for the fault springs is primarily bedrock and the springs generally occur near the base of the mountain fronts. The seep springs generally occur in the lower parts of the valley and are of little use either for culinary purposes or for irrigation. Much of the water from these seep springs is wasted by useless phreatophytes.

Young and Carpenter (1961, p. 2) list the most promising areas within this region for the development of ground-water and give an estimate of the water in storage in these areas. These most promising areas are: (1) the southern part of Circle Valley in the vicinity of

Circleville, (2) the area between Central and Venice, and (3) the Sevier Bridge Reservoir bottom. The estimates given of the water in storage in these areas were 200,000 acre-feet for Circle Valley, 800,000 acre-feet for the Central-Venice area, and 300,000 acre-feet for the Sevier Bridge Reservoir area. Figure 2 of this report shows the boundaries of these areas.

Western Region

Bedrock in the western region contains only small quantities of water and in many localities these rocks dip away from the valleys and, therefore, the conditions are unfavorable for the recovery of ground water. These rocks are primarily Paleozoic quartzite, limestone, dolomite, and shale with water occurring only where they have been highly jointed and fractured or in solution cavities. Sandstone and conglomerate in Pavant, Tushar, and Canyon ranges contain small quantities of ground water but are only locally important as water sources.

Ground water accumulates in some areas near the surface in igneous rocks that have disintegrated to form coarse-grained porous debris. This water gives rise to seep springs and provides a source of water for shallow wells (Meinzer, 1911, p. 29-30).

The unconsolidated valley sediments of this region consist of stream deposits, a large thickness of Bonneville lake sediments, and alluvial fan deposits. Except near the highlands the materials deposited in Lake Bonneville are predominantly fine-grained lake-bottom sediments that yield little water (Meinzer, 1911, p. 33).

The alluvial fans extending from the pediments of the mountain fronts to the stream and lake deposits of the central part of the

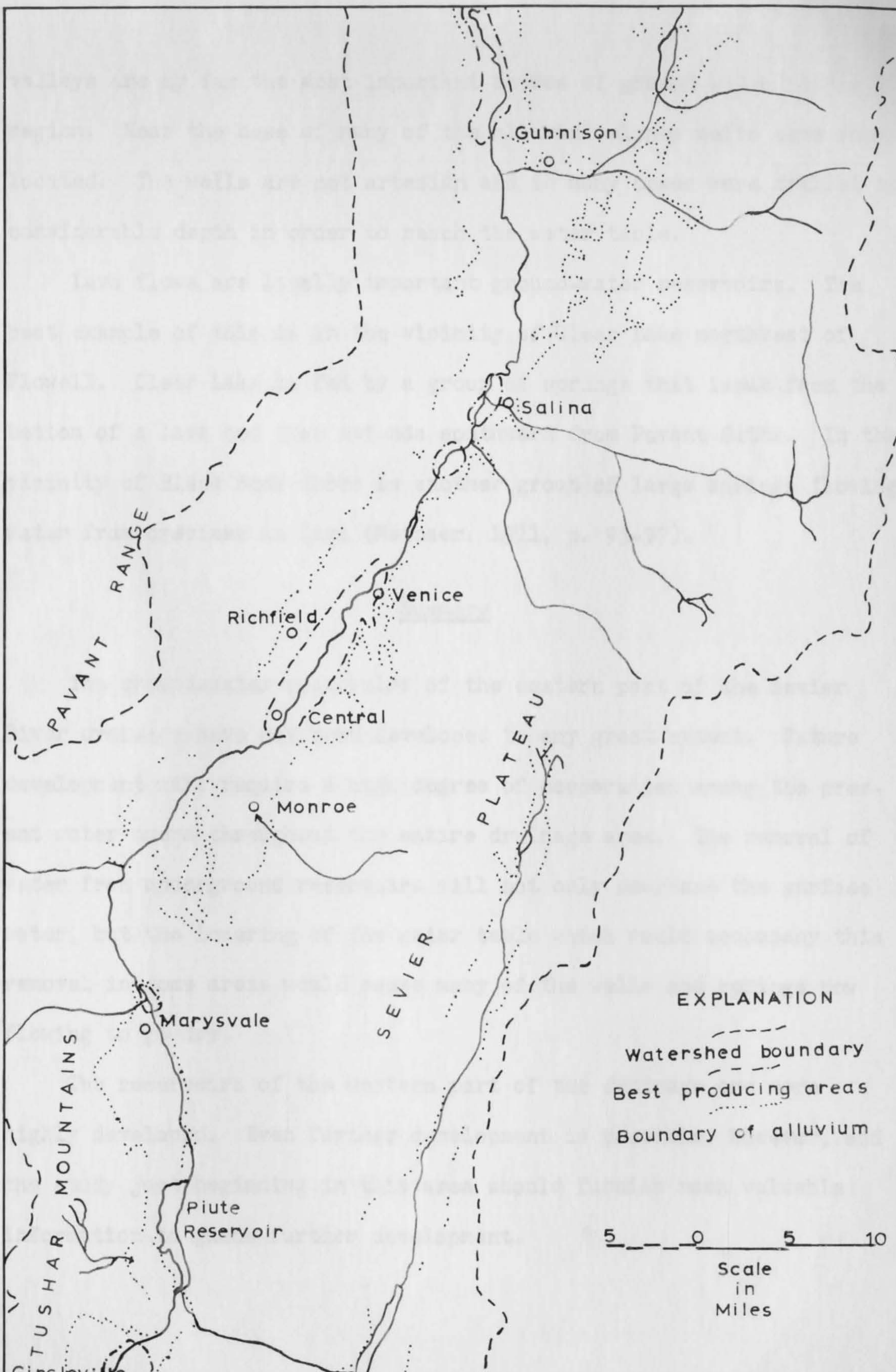

Figure 2. Ground-water areas of central Sevier Valley (After Young and Carpenter, 1961, Figure 1)

valleys are by far the most important source of ground water in the region. Near the base of many of the alluvial slopes wells have been located. The wells are not artesian and in many cases were drilled to considerable depth in order to reach the water table.

Lava flows are locally important ground-water reservoirs. The best example of this is in the vicinity of Clear Lake northwest of Flowell. Clear Lake is fed by a group of springs that issue from the bottom of a lava bed that extends southward from Pavant Butte. In the vicinity of Black Rock there is another group of large springs flowing water from crevices in lava (Meinzer, 1911, p. 95-97).

Summary

The ground-water reservoirs of the eastern part of the Sevier River drainage have not been developed to any great extent. Future development will require a high degree of cooperation among the present water users throughout the entire drainage area. The removal of water from underground reservoirs will not only decrease the surface water, but the lowering of the water table which would accompany this removal in some areas would cause many of the wells and springs now flowing to go dry.

The reservoirs of the western part of the drainage are more highly developed. Even further development is possible, however, and the study just beginning in this area should furnish much valuable information to guide further development.

OIL AND GAS

General Statement

The Sevier River drainage area has undergone sporadic oil and gas exploration since the early 1900's with no commercial production having been established. However, the existence of a number of possible hydrocarbon traps and a thick section of marine sedimentary rocks in the area suggest that further exploration is justified.

To the east of this area in western Emery and Carbon Counties, production has been established. Here several gas fields have been discovered and developed.

The Sevier drainage, in general, lies within a transitional area between two distinct physiographic provinces, the Basin and Range Province and the Colorado Plateaus. The geology of this transitional region is complex both in structure and stratigraphy. This condition complicates oil and gas exploration but it also adds to the prospectiveness of the area. Complex folding and faulting has provided a number of possible oil and gas traps, while the varying nature of sedimentation in many parts of this region appears to have provided conditions favorable for stratigraphic entrapment of hydrocarbons.

Of particular importance in the exploration for oil and gas in this area is the degree in which subsurface folding is reflected by surface features. Considerable discordance probably exists in many parts of this region. Exploration is further complicated by the existence of gypsum, anhydrite, and salt beds of great areal extent. These beds greatly hamper seismographic exploration.

A thick section of Paleozoic, Mesozoic, and Tertiary marine rocks underlies the Sevier River drainage area. A number of rock units within this section, particularly in the Mesozoic and Tertiary sections of the northeastern portion of the area, are correlative in age and lithologies with rocks which are productive on the Wasatch Plateau and in the Uinta Basin. Where proper entrapment exists many of these rock units could be oil- or bas-bearing.

A 36-inch pipeline has been proposed by the El Paso Natural Gas Company to connect the Utah-Wyoming producing areas with the large California market (Petroleum Publishing Co., 1962). This pipeline is to run through west central and southwestern Utah and should provide added incentive for additional exploration throughout this entire region.

Drilling Activity

The first drilling for oil and gas within the Sevier River drainage was accomplished during 1902 in the Fillmore area. Since that time there has been some drilling activity in all of the counties within this drainage area, with the exception of Piute County. All of the wells drilled were dry and abandoned. Table 3 shows the name, location, and other important data on each of these wells. Much of the data presented was taken from Hansen and Bell (1949, p. 146 and 160).

Table 3. Tabulation of wells drilled for oil and gas within the Sevier River drainage

Operator	Area	Date abandoned	Location	Total depth
Juab County				
Central Utah Gas & Oil	Sage Valley		SE 12-15S2W	450'
Sage Valley Oil Co.	Sage Valley	1947	NW 12-15S2W	1200'
Mt. Nebo Oil Co.	Juab	1912	1-15S1W	2900'
Standard Oil of Calif.	Levan	1-28-60	SW 32-15S1E	7435'
Millard County				
Tom Kearns	Fillmore	1910 ?	12-20S5W	1920'
Westwood Oil Co.	Fillmore	1902	SW 36-20S5W	920'
Westwood Oil Co.	Fillmore	1914	SW 36-20S5W	1200'
Premium Oil Co.	Preuss Valley		32-25S13W	600'
Beaver Valley Oil Co.	Black Rock	1930	SE 19-25S9W	1545'
Beaver Valley Oil Co.	Black Rock	1930	NE 20-25S9W	3500'
H. T. Kaminska	Black Rock	1922	NE 31-25S9W	800'
Sanpete County				
S. Jenson	Mt. Pleasant	1918 ?	SE 27-15S4E	1408'
Producers Oil Co.	Ephraim	1920	SW 3-17S3E	921'
Sanpete Oil Co.	Redmond		SW 24-29S1W	1462'
Gunnison Oil Co.	Gunnison		NW 32-18S1E	1800'
Ben H. Bullock *et al.*	Redmond	1941	SW 24-20S1W	85'
Tenn. Gas Transmission	Moroni	1958	NE 16-15S3W	9995'
Sevier County				
Sanpete Oil Co.	Redmond		NE 36-20S1W	250'
American Liberty Oil Co.	Sevier	1948	SW 13-25S5E	4493'
Albrecht and Assoc.	Sevier	5-26-58	25-21S1W	734'
Standard Oil of Calif.	Sigurd	10-25-57	SE 32-22S1W	9516'

Summary

Although there have been no commercial oil or gas accumulations discovered within the Sevier River drainage, the area has not been completely condemned. A thick section of marine sedimentary rocks exists in this area which contains several potential source and reservoir beds. In addition, a number of potential hydrocarbon traps exist in this geologically complex region that have not been fully evaluated by drilling.

Possible discordance between surface and subsurface folding is an important problem to be considered in any further exploration in this area. Another problem of particular importance to seismographic exploration is the widespread deposits of gypsum, anhydrite, and salt.

A greatly enlarged market will be provided by the completion of the pipeline now proposed to connect the Utah-Wyoming producing areas with California. This should provide additional incentive for expanded exploration activity throughout this entire region, including the Sevier River drainage.

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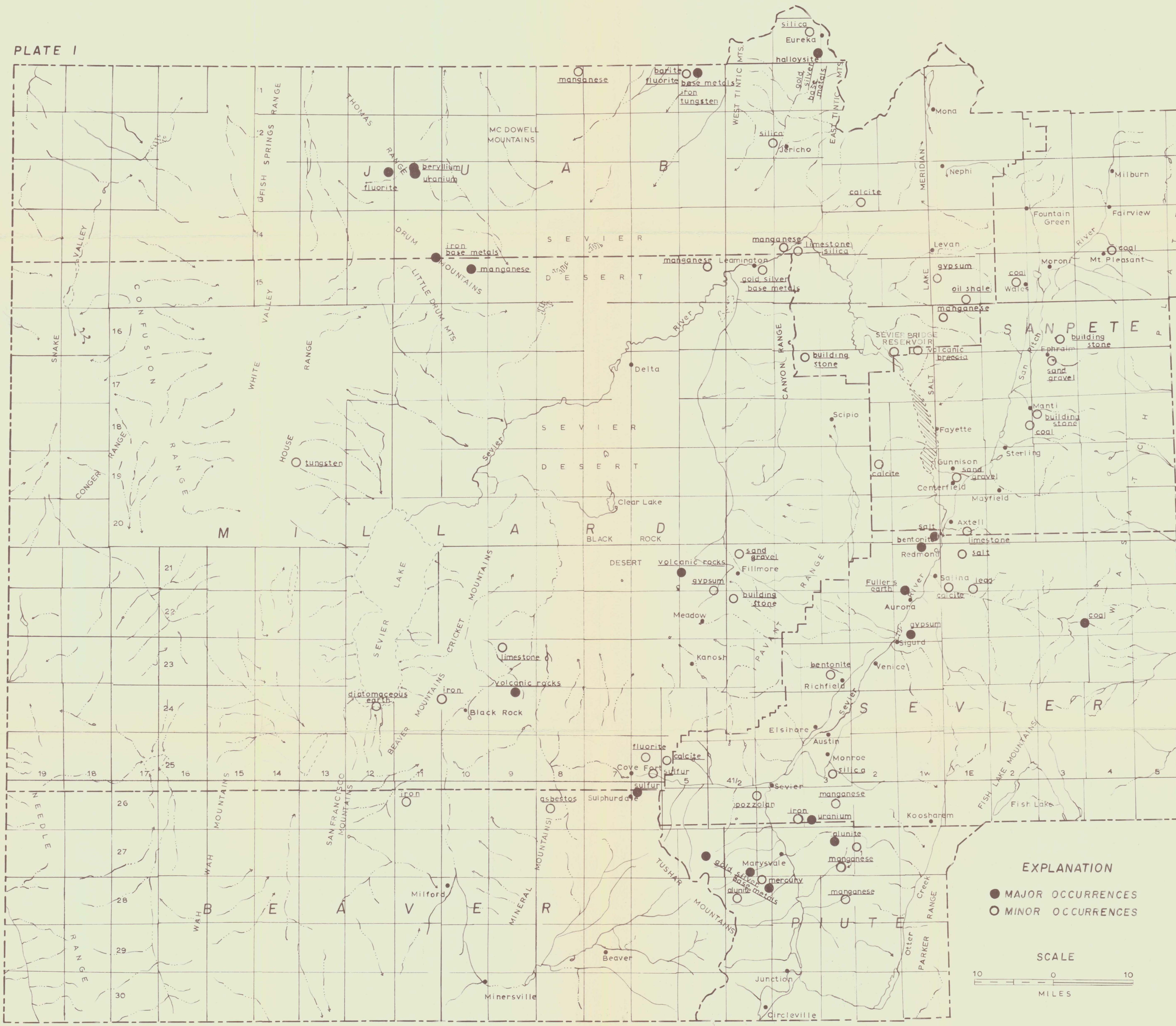
PLATE I



MINERAL RESOURCES OF THE SEVIER RIVER DRAINAGE

BY DAVID T. SANDERS